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Indian Standard

ELECTROTECHNICAL VOCABULARY

PART XVI LIGHTING

Section I General Aspects

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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November 1968

Indian Standard
ELECTROTECHNICAL VOCABULARY
PART XVI LIGHTING
Section 1 General Aspects

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Indian Standard
ELECTROTECHNICAL VOCABULARY
PART XVI LIGHTING
Section I General Aspects

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 16 January 1968, after the draft finalized by the Electrotechnical Standards Sectional Committee in consultation with the Illuminating Engineering Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard (Part XVI/Section 1) is based, to a large extent, upon Publication No. 50 (45) on 'International electrotechnical vocabulary' issued by the International Electrotechnical Commission. This section deals with the general aspects of lighting, covering terms relating to radiation, colorimetry, optical properties of matter, photometric quantities and units, eye and vision and the production of light. Section 2 of this standard covers terms relating to luminaires and lighting for traffic and signalling and Section 3 deals with terms relating to lamps and auxiliaries.

0.3 A compromise has been made between absolute precision and simplicity in order to arrive at the most apt definitions. The principal object of this terminology is to provide definitions which are sufficiently clear so that each term can be understood with the same meaning in the electronic field. Thus, it may sometimes be felt that the definitions used in this standard are not sufficiently precise, do not include all cases, do not take account of certain exceptions or are not identical with those which may be found in other publications designed with other objects and for other readers. Such imperfections are inevitable and sometimes have to be accepted in the interest of simplicity and clarity.

0.4 The electrotechnical vocabulary is being prepared in several parts, each having one or more sections.

1. SCOPE

1.1 This standard (Part XVI/Section 1) covers definitions of terms used in the field of lighting relating to the general aspects, namely, radiation, colorimetry, photometric quantities and units, optical properties of matter eye and vision and the production of light.

2. RADIATION

2.1 Fundamental Concepts

2.1.1 *Radiation*

a) Emission or transfer of energy in the forms of electromagnetic waves or particles.

b) Electromagnetic waves or particles.

NOTE — In general, nuclear radiations and radio waves are not considered in this vocabulary but only optical radiations, that is, electromagnetic radiations (photons) of wavelength lying between the region of transition to X-rays ($\approx$1 nm) and the region of transition to radio waves ($\approx$1 mm).

2.1.2 *Irradiation* — Application of radiation to an object.

2.1.3 *Monochromatic Radiation* — Radiation characterized by a single frequency. By extension, radiation of a very small range of frequency or wavelength, which can be described by stating a single frequency or wavelength.

2.1.4 *Complex Radiation* — Radiation composed of a number of monochromatic radiations.

2.1.5 *Visible Radiation* (*Light*) — Any radiation capable of causing a visual sensation directly. The wavelength limits adopted by Committee E-2.1.2 of CIE (Vienna 1963) for the spectral range of this radiation are 400 and 760 nm.

NOTE — The limits of the spectral range of visible radiation are not well defined and may vary according to the user. The lower limit is generally taken between 380 and 400 nm and the upper limit between 760 and 780 nm [1 nanometre (nm) = 10^{-9} m].

2.1.6 *Infrared Radiation* — Radiation for which the wavelengths of the monochromatic components are greater than those for visible radiation and less than about 1 millimetre.

NOTE — The limits of the spectral range of infrared radiation are not well defined and may vary according to the user. Committee E-2.1.2 of CIE distinguishes in this spectral range:

IR-A	780 to 1 400 mm
IR-B	1, 4 to 3 μm
IR-C	3 μm to 1 mm

2.1.7 *Ultraviolet Radiation* — Radiation for which the wavelengths of the monochromatic components are smaller than those for visible radiation and more than about 1 nanometre.

NOTE — The limits of the spectral range of ultraviolet radiation are not well defined and may vary according to the user. Committee E-2.1.2 of CIE distinguishes in this spectral range:

UV-A	315 to 400 nm
UV-B	280 to 315 nm
UV-C	100 to 280 nm

2.1.8 *Spectrum of a Radiation*

a) Spatial display of a complex radiation produced by separation of its monochromatic components.

b) Composition of a complex radiation.

NOTE — Examples of sense (b) : continuous spectrum, line spectrum.

2.1.9 *Spectrum Line* — Image (generally of a slit) produced, in a dispersing system, by a monochromatic radiation.

NOTE — Also used in the sense of: A monochromatic radiation emitted or absorbed in a transition between two atomic or molecular levels.

2.1.10 *Emission* — Release of radiant energy.

2.1.11 *Reflection* — Return of radiation by a surface without change of frequency of the monochromatic components of which the radiation is composed.

2.1.12 *Transmission* — Passage of radiation through a medium without change of frequency of the monochromatic components of which the radiation is composed.

2.1.13 *Absorption* — Transformation of radiant energy to a different form of energy by interaction with matter.

2.1.14 *Diffusion* — Change of the spatial distribution of a beam of radiation when it is deviated in many directions by a surface or by a medium.

2.1.15 *Rayleigh Scatter in a Medium* — Diffusion of radiation in the course of its passage through a medium containing particles the size of which is small compared with the wavelength of the radiation.

2.1.16 *Refraction* — Change in the direction of propagation of radiation determined by change in the velocity of propagation in passing through an optically non-homogeneous medium, or in passing from one medium to another.

2.1.17 *Dispersion*

a) Dependence of the velocity of propagation of a radiation on its frequency, whereby a separation of the monochromatic components of a complex radiation is possible.

b) Property of an optical device or medium giving rise to the phenomenon.

c) Quantity characterizing this property.

2.1.18 *Interference* — Attenuation or reinforcement of the amplitudes of the vibrations of a radiation, occurring where coherent wave-trains overlap.

2.1.19 *Diffraction* — Deviation of the direction of propagation of a radiation, determined by the wave nature of radiation, and occurring when the radiation passes the edge of an obstacle.

2.1.20 *Photon* — Elementary quantity of radiant energy (quantum) whose value is equal to the product of Planck's constant *h* and the frequency of the electromagnetic radiation.

2.1.21 *Point Source* — Source of radiation the dimensions of which are small enough compared with the distance between source and receptor, so that they may be neglected in photometric calculations.

2.1.22 *Uniform Point Source* — A point source which emits uniformly in all directions.

2.2 Quantities

2.2.0 *General*

2.2.0.1 *Distinction between radiant and luminous quantities* — Pure physical quantities for which radiation is evaluated in energy units are defined in this clause. Each one of these quantities corresponds to another quantity for which the radiation is evaluated by means of a standard photometric observer. These two kinds of quantities are represented by the same principal symbol distinguished by adding the subscript *e* (energy) in the case of physical quantities, and the subscript *v* (visual) in the case of photometric quantities. To have no possibility of confusion, the subscripts may be omitted.

2.2.0.2 *Use of the adjective 'spectral'* — When certain quantities, such as emissivity, luminous efficacy, transmittance, etc, are considered for monochromatic radiation, they are functions of wavelength (or frequency, or wave number, etc); they may then be designated by the same term preceded by the adjective *spectral*, and by the same symbol followed by λ (or γ, or σ, etc) in parenthesis; example: spectral emissivity, $\varepsilon(\lambda)$.

If the spectral concentration of a quantity X is considered, it may also be designated by way of abbreviation by the name of the quantity preceded by the adjective *spectral* as before, and by the symbol for the quantity with the subscript λ (or γ, or σ, etc), but care shall be taken to remember that X and $X\lambda$ are quantities of a different kind because

$$X\lambda = \frac{dX}{d\lambda}$$

2.2.1 *Period* — Size of the minimum interval of the independent variable after which the same characteristics of a periodic phenomenon recur.

NOTE — In radiation the independent variable is the time and the corresponding quantity is known as the periodic time.

symbol T
unit: second (s)

2.2.2 *Frequency* — Reciprocal of the period.

symbol f, γ

NOTE — When the independent variable is time, the unit of frequency is the hertz: symbol Hz (1 Hz = 1s^{-1}). (This unit is also called 'cycle per second', c/s.)

2.2.3 *Wavelength* — Distance in the direction of propagation of a periodic wave between two successive points at which the phase is the same (at the same time).

symbol λ
unit : metre (m)

NOTE 1 — The wavelength in a medium is equal to the wavelength in vacuo divided by the refractive index of the medium. Unless otherwise stated, values of wavelength are generally those in air. The refractive index of standard air (15°C, 101 325 $N.m^{-2}$) lies between 1·000 27 and 1·000 29 for visible radiations.

NOTE 2 — The reciprocal of the wavelength is the *wavenumber*:

symbol σ
unit : m^{-1}

2.2.4 *Radiant Energy* — Energy emitted, transferred or received as radiation.

symbol Q_e, Q
unit : joule (J) (1 J = W.s)

NOTE — In ultraviolet radiation therapy and biology this quantity is called *integral dose* (International Photobiology Committee, 1954).

2.2.5 *Radiant Flux*; *Radiant Power* — Power emitted, transferred, or received in the form of radiation.

symbol Φ_e, Φ, P

$$\Phi_e = \frac{dQ_e}{dt}$$

unit : watt (W)

2.2.6 *Radiant Efficiency of a Source of Radiation* — Ratio of the radiant flux emitted to the power consumed.

symbol η_e, η

NOTE — The radiant efficiency of a source in a limited region of the spectrum may also be considered, that is, the ratio of the radiant flux emitted in this spectral region to the power consumed.

2.2.7 *Radiant Intensity of a Source in a Given Direction* — Quotient of the radiant flux leaving the source, propagated in an element of solid angle containing the given direction, by the element of solid angle.

symbol I_e, I

$$I_e = \frac{d\Phi_e}{d\Omega}$$

unit : watt per steradian ($W.sr^{-1}$)

NOTE — For a source which is not a point source : The quotient of the radiant flux received at an elementary surface by the solid angle which this surface subtends at any point of the source, when this quotient is taken to the limit as the distance between the surface and the source is increased.

2.2.8 *Radiance in a Given Direction, at a Point on the Surface of a Source or a Receptor, or at a Point on the Path of a Beam* — Quotient of the radiant flux leaving, arriving at, or passing through an element of surface at this point and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone and the area of the orthogonal projection of the element of surface on a plane perpendicular to the given direction.

symbol L_e, L

$$L_e = \frac{d\Phi_e}{d\Omega .\ dA.\ \cos\theta}$$

unit : watt per steradian and per square metre ($W.\ sr^{-1}.\ m^{-2}$)

NOTE — Three special cases may be noted:

Case 1 — At a point on the surface of a source, in a given direction, radiance is also the quotient of the radiant intensity in the given direction of an element of the surface at this point, by the area of the orthogonal projection of this element on a plane perpendicular to this direction (radiant intensity per unit projected area).

$$L_e = \frac{dI_e}{dA.\ \cos\theta}$$

Case 2 — At a point on the surface of a receptor, in a given direction, radiance is also the quotient of the irradiance which is received at this point on a surface perpendicular to the given direction, by the solid angle of the elementary cone containing this direction and surrounding the beam which produces this irradiance (perpendicular irradiance per unit solid angle).

$$L_e = \frac{dE_e}{d\Omega}$$

Case 3 — On the path and in the direction of an element of a beam, in a non-diffusing, non-absorbing medium, the radiance is also the quotient of the radiant flux $d\,\phi_e$ which transports the beam, by the geometric extent dG of the beam. The *geometric extent*, which may be defined by two sections of the beam of areas dA and dA′, of separation l and having angles θ and θ' between their normals and the direction of the beam is $dG = dA.\ \cos\theta.\ d\Omega$, where the numerical value in steradians of $d\Omega$ is $dA'.\ \cos\theta\ ,\ l^{-2}$.

$$L_e = \frac{d\phi_e}{dG} = \frac{d^2\phi_e}{d\Omega .\ dA.\ \cos\theta}$$

In the absence of diffusion, it can be demonstrated in geometrical optics that the *optical extent*, product of the geometric extent of an element of a beam and the square of the refractive index of the medium of propagation, is an invariant along the length of the beam whatever the deviations which it undergoes by reflection or refraction ($dG.\ n^2 = \text{constant}$). In consequence, the *basic radiance*, quotient of the radiance by the square of the refractive index, is invariant along the length of an element of a beam if the losses by absorption or by reflection are taken as zero ($L_e\ .\ n^{-2} = \text{constant}$).

2.2.9 *Radiant Flux (Surface) Density* — At a point of a surface quotient of the radiant flux at an element of the surface containing the point, by the area of that element.

symbol ......

$$\ldots\ldots = \frac{d\Phi_e}{dA}$$

unit : watt per square metre ($W.m^{-2}$)

2.2.10 *Irradiance at a Point of a Surface* — Quotient of the radiant flux incident on an element of the surface containing the point, by the area of that element.

symbol E_e, E

$$E_e = \frac{d\Phi_e}{dA}$$

unit : watt per square metre ($W.m^{-2}$)

Note — In ultraviolet radiation therapy and photobiology this quantity is called *dose-rate* (International Photobiology Committee, 1954).

2.2.11 *Radiant Exposure at a Point of a Surface* — Surface density of the radiant energy received.

symbol H_e, H

$$H_e = \frac{dQ_e}{dA} = \int E_e dt$$

unit : joule per square metre ($J.m^{-2}$)

Note 1 — *Formerly irradiation.*

Note 2 — Equivalent definition : Product of an irradiance and its duration.

Note 3 — In ultraviolet radiation therapy and photobiology this quantity is called *dose* (International Photobiology Committee, 1954).

2.2.12 *Radiant Exitance at a Point of a Surface* — Quotient of the radiant flux leaving an element of the surface containing the point, by the area of that element.

symbol M_e, M

$$M_e = \frac{d\Phi_e}{dA} = \int L_e . \cos\theta \, d\Omega$$

unit : watt per square metre ($W.m^{-2}$)

Note 1 — The name *radiant emittance* previously given to this quantity is abandoned because it has given rise to confusion. Thus the term *emittance* has been used to designate either the flux per unit area leaving a surface (whatever the origin of the flux), or the flux per unit area emitted by a surface (flux originating in the surface).

Note 2 — The expression *self-radiant exitance* ($M_{e,s}$) indicates that the flux considered does not include reflected or transmitted flux.

The expression *thermal radiant exitance* ($M_{e,th}$) indicates that the flux considered is produced by thermal radiation.

These same adjectives (*self, thermal*) are equally applicable to other quantities such as luminance, etc.

Note 3 — In the case of a full radiator (blackbody) the radiance L_e is uniform in all directions. In consequence, when the solid angle is measured in steradians, the radiant exitance has the numerical value $M_e = \pi L_e$.

2.2.13 *Emissivity of a Thermal Radiator* — Ratio of the thermal radiant exitance of the radiator to that of a full radiator at the same temperature.

symbol ε

$$\varepsilon = \frac{M_{e,th}}{M_{e(\varepsilon=1)}}$$

2.2.14 *Directional Emissivity of a Thermal Radiator* — Ratio of the thermal radiance of the radiator in a given direction to that of a full radiator at the same temperature.

symbol $\varepsilon(\theta, \varphi)$

$$\varepsilon(\theta, \varphi) = \frac{L_{e,th}(\theta, \varphi)}{L_{e,(\varepsilon = 1)}}$$

where θ and φ are the angular coordinates defining the given direction.

2.2.15 *Spectral Concentration of a Radiometric Quantity*: *Radiant Flux, Radiant Intensity, etc* — Quotient of the quantity, taken over an infinitesimal range on either side of a given wavelength, by the range.

$$X_{e,}\lambda = \frac{dX_e}{d\lambda}$$

NOTE 1 — Frequencies, wavenumbers or their logarithms may also be used; if there is a risk of ambiguity this should be avoided by means of the wording: 'spectral concentration in terms of frequency', etc.

NOTE 2 — *See* **2.2.0.2**.

2.2.16 *Spectral Distribution Curve of a Radiometric Quantity*: *Radiant Flux, Radiant Intensity, etc* — Curve representing the spectral concentration of the quantity as a function of wavelength.

NOTE 1 — *See* Note 1 to **2.2.15**.

NOTE 2 — Commonly the *relative spectral distribution curve* is used, that is the curve representing the ratio of the spectral concentration of the quantity to a certain value of the same quantity.

2.2.17 (*Relative Spectral*) *Energy* (*Power*) *Distribution* — Description of the spectral character of a radiation (description of an illuminant) by the way in which the relative spectral concentration of radiant energy varies throughout the spectrum.

symbol $S(\lambda)$

2.3 Thermal Radiation — Process of emission in which the radiant energy originates in the thermal agitation of the particles of matter (atoms, molecules, ions)

2.3.1 *Thermal Radiator* — Source emitting by thermal radiation.

2.3.2 *Full Radiator, Planckian Radiator* — Thermal radiator which absorbs completely all incident radiation, whatever the wavelength, the direction of incidence or the polarization. This radiator has, for any wavelength, the maximum spectral concentration of radiant exitance at a given temperature.

2.3.3 *Planck's Law* — Law giving the spectral concentration of radiant exitance of a full radiator as a function of wavelength and temperature.

For the total radiation emitted (unpolarized):

$$M_{e,\lambda}(\lambda, T) = \frac{\partial M_e(\lambda, T)}{\partial \lambda} = c_1 \lambda^{-5}\left(e^{\frac{c_2}{\lambda T}} - 1\right)^{-1}$$

$$c_1 = 2\pi hc^2 = (3{\cdot}741\,50 \pm 0{\cdot}000\,09) \times 10^{-16}\ \mathrm{W.m^2}$$

$$c_2 = \frac{hc}{k} = (1{\cdot}438\,79 \pm 0{\cdot}000\,06) \times 10^{-2}\ \mathrm{m.^\circ K}$$

(Numerical values according to E.R. Cohen and J.W.M. Dumond, *Rev. Mod. Phys.*, 37, 1965, P 590. The error quoted for c_1 and c_2 represents the standard deviation. The wavelength λ is expressed in metres.

In the text of the ' Internation Practical Temperature Scale, 1948, amended edition 1960 ', c_2 is taken as $1{\cdot}438 \times 10^{-2}$ m.°k.)

h, Planck's constant
c, velocity (speed) of light in vacuum
T, absolute temperature
k, the Boltzmann constant

NOTE — It is recommended that the constant c_1 is always used with the meaning indicated above. The numerical constants applicable to other aspects of the radiation emitted are shown below. They should be designated c_1 multiplied by an appropriate factor:

$\pi hc^2 = \frac{c_1}{2}$ (for the exitance of the polarized radiation)

$2hc^2 = \frac{c_1}{\pi}$ (for the radiance of the non-polarized radiation)

$hc^2 = \frac{c_1}{\pi}$ (for the radiance of the polarized radiation)

$8\pi hc = \frac{4c_1}{c}$ (for the energy per unit volume of the non-polarized radiation, etc).

For example, the spectral radiance of the non-polarized radiation, which is often used, should be written:

$$L_{e,\lambda}(\lambda, T) = \frac{\partial L_e(\lambda, T)}{\delta \lambda} = \frac{c_1}{\pi \Omega_0} \lambda^{-5}\left(e^{\frac{c_2}{\lambda T}} - 1\right)^{-1}$$

where Ω_0 is the magnitude of the solid angle of 1 steradian.

2.3.4 *Wien's Law (of Radiation)* — Approximate form of Planck's law, obtained by neglecting the term 1 inside the brackets in the formula for this law. This approximation is valid when T is sufficiently small.

NOTE — The approximation is valid to better than one part in a thousand when λT is smaller than 0·002 m.°k (for example, in red light for T less than 3 500°K).

$$M_{e,\lambda}(\lambda, T) = c_1 \lambda^{-5} e^{-\frac{c_2}{\lambda T}}$$

2.3.5 *Rayleigh-Jeans Law* — Approximate form of Planck's law, obtained by neglecting in the formula for this law the terms of higher order in the series expansion of the exponential. This approximation is valid when λT is sufficiently large.

NOTE — The approximation is valid to better than one part in a hundred when λT is larger than 0·72 m.°K (for example, in the infrared at a wavelength of 0·1 mm for T greater than 7 200°K).

$$M_{e,\lambda}(\lambda, T) = \frac{c_1}{c_2}\lambda^{-4}T = 2\pi c\lambda^{-4}kT$$

2.3.6 *Stefan-Boltzmann Law* — Relation between the radiant exitance of a full radiator and its temperature.

$$M_e = \sigma T^4$$

$$\sigma = \frac{2\pi^5 k^4}{15\,h^3 c^2} = (5{\cdot}669\,7 \pm 0{\cdot}001\,0) \times 10^{-8}\ \mathrm{W.m^{-2}\,{}^{\circ}K^{-4}}$$

(Numerical values according to E. R. Cohen and J.W.M. Dumond, *Rev. Mod. Phys.*, 37, 1965, P 590). The error quoted represents the standard deviation.

2.3.7 *Kirchhoff's Law* — At a point of the surface of a thermal radiator at each temperature and for each wavelength, the spectral directional emissivity is equal to the spectral absorptance for radiation incident in the same direction.

NOTE — The same equality holds good for any one polarized component of the radiation emitted or absorbed by the thermal radiator.

2.3.8 *Non-selective Radiator* — Thermal radiator whose spectral emissivity is independent of wavelength over the range considered.

2.3.9 *Selective Radiator* — Radiator whose spectral emissivity depends on the wavelength over the range considered.

2.3.10 *Grey Body* — Non-selective radiator whose spectral emissivity is smaller than 1.

2.3.11 *Full Radiator Temperature (of a Thermal Radiator)* — Temperature of full radiator at which it has the same radiant thermal exitance as the radiator considered.

unit : degree Kelvin (°K)

2.3.12 *Radiance Temperature (Luminance Temperature) of a Thermal Radiator for a Wavelength* — Temperature of a full radiator for which the radiance at the specified wavelength has the same spectral concentration as for the radiator considered.

unit : degree Kelvin (°K)

NOTE — In visual pyrometry, the reference wavelength is generally 655 nm.

2.3.13 *Distribution Temperature* — Temperature of the full radiator for which the ordinates of the spectral distribution curve of its radiance are proportional (or approximately so), in the visible region, to those of the distribution curve of the radiation considered.

unit: degree Kelvin (°K)

NOTE — Both radiations will necessarily have the same or nearly the same chromaticity.

2.3.14 *Colour Temperature* — Temperature of the full radiator which emits radiation of the same chromaticity as the radiation considered.

unit: degree Kelvin (°K)

NOTE — The corresponding relative spectral distribution curves may not be similar, but there will be a metameric match.

3. PHOTOMETRIC QUANTITIES AND UNITS

3.0 General

3.0.1 Many terms, among others 'light' (**6.24**), may be considered from the sensory (subjective) point of view; this use is dealt with mainly in **6**. They also have a physical meaning which is amenable to mathematical treatment; this is the point of view which predominates in this clause.

3.0.2 If, for particular scientific purposes, certain of the following definitions should refer to a $V(\lambda)$ [$V'(\lambda)$] which is that of an individual observer, this should be stated explicitly. Unless otherwise stated, the photometric quantities refer to the single and unique [$V(\lambda)$] [$V'(\lambda)$] which is international and defines the *standard/observer* photometric.

3.0.3 Most of the following quantities and units may be defined in two different ways:

for photopic vision (CIE 1924)

for scotopic vision (CIE 1951)

Unless otherwise stated, the quantity or unit always refers to photopic vision (*see* **3.2**).

If the quantity or unit is intended to refer to scotopic vision, the term should be qualified by the word 'scotopic'.

3.0.4 On the distinction between radiant and luminous quantities, and on the use of the adjective *spectral*, *see* **2.2.0.1** and **2.2.0.2**.

3.0.5 The term efficiency has been reserved for the dimensionless quantity that is a ratio which cannot exceed unity (100 percent). If the quantity has dimensions (that is, it is a quotient) the term used is *efficacy*.

3.1 Light — *See* 6.24.

3.1.1 *Illumination* — Application of visible radiation (light) to an object.

3.2 Spectral Luminous Efficiency of a Monochromatic Radiation of Wavelength — Ratio of the radiant flux at wavelength λ_m to that at wavelength λ, both radiations producing equally intense luminous sensations under specified photometric conditions and λ_m being chosen so that the maximum value of this ratio is equal to 1.

symbol [$V(\lambda)$] for photopic vision
[$V'(\lambda)$] for scotopic vision

NOTE — Unless otherwise indicated, the values used for the spectral luminous efficiency in *photopic vision* are the values agreed internationally in 1924 by CIE and adopted in 1933 by the International Committee of Weights and Measures (*see* Table 1). These values define the V (λ) *function* or V (λ) *curve.* For *scotopic vision,* CIE adopted provisionally in 1951 the values of Table 1 for the standard/observer (young observers) photometric.

3.3 Luminous Flux — Quantity derived from radiant flux by evaluating the radiation according to this action upon a selective receptor, the spectral sensitivity of which is defined by the standard spectral luminous efficiencies.

symbol Φ_v, Φ
unit : lumen (lm)

NOTE — Unless otherwise indicated, the luminous flux in question relates to photopic vision and is connected with the radiant flux in accordance with the formula adopted in 1948 by CIE, that is by the relation

$$\phi v = K_m \int \frac{d\phi_e}{d\lambda} V(\lambda)\, d\lambda$$

in which $\frac{d\phi_e}{d\lambda} d\lambda$ is the radiant flux corresponding to the radiation comprised between λ and $\lambda + d\lambda$ and $V(\lambda)$ is the spectral luminous efficiency, the values of which as a function of λ are given in Table 1. Applied to the radiation of a full radiator at the freezing temperature of platinum the preceding formula determines the value of K_m ($lm.\ W^{-1}$) (*see* 3.7).

TABLE 1 SPECTRAL LUMINOUS EFFICIENCY FOR THE STANDARD OBSERVER PHOTOMETRIC

(*Clauses* 3.2 *and* 3.3)

	PHOTOPIC VISION	SCOTOPIC VISION
λ (nm)	V (λ)	V′ (λ)
380	0·000 0	0·000 589
390	0·000 1	0·002 209
770	0·000 03	0·000 000 241
780	0·000 015	0·000 000 139

3.4 Lumen — SI unit of luminous flux : Luminous flux emitted within unit solid angle (one steradian) by a point source having a uniform intensity of 1 candela (adopted in 9th General Conference of Weights and Measures, 1948).

symbol lm

3.5 Quantity of Light — Product of luminous flux and its duration.

symbol Qv, Q

$$Qv = \int \Phi\, v^{dt}$$

unit : lumen-second (lm.s)

3.6 Lumen-Second — SI unit of quantity of light: Quantity of light equal to 1 lumen radiated or received for a period of 1 second.

symbol lm.s

NOTE — Other unit is lumen-hour, the symbol being (lm.h).

3.7 Luminous Efficacy of Radiation — Quotient of luminous flux by the corresponding radiant flux.

unit : lumen per watt (lm.W^{-1}) at about — 555 nm

For a complex radiation:

symbol K

$$K = \frac{\Phi v}{\Phi e}$$

For a monochromatic radiation of wavelength λ (*spectral luminous efficacy*).

symbol K (λ)

$$K(\lambda) = \frac{\Phi_{v,\lambda}}{\Phi_{e,\lambda}} = \frac{\frac{d\Phi_v}{d\lambda}}{\frac{d\Phi_e}{d\lambda}} = K_m V(\lambda)$$

The *maximum spectral luminous efficacy*, maximum value of K (λ), is denoted by the symbol K_m; its value is $K_m \approx 680\ \text{lm.W}^{-1}$ (for the standard observer, photometric, in photopic vision).

NOTE — Formerly *luminous efficiency*.

3.8 Luminous Efficiency of Complex Radiation — Ratio of radiant flux weighted according to V (λ) to the corresponding radiant flux.

symbol V

$$V = \frac{\int_0^\infty \Phi_{e,\lambda}\, V(\lambda)\, d\lambda}{\int_0^\infty \Phi_{e,\lambda}\, d\lambda} = \frac{K}{K_m}$$

NOTE 1 — This ratio is also the ratio of the luminous efficacy of the complex radiation, K, to the maximum spectral luminous efficacy, K_m.

NOTE 2 — For the spectral luminous efficiency

$$V(\lambda) = \frac{K(\lambda)}{K_m}, \quad (\textit{see } \mathbf{3.2}).$$

3.9 Luminous Efficacy of a Source — Quotient of the luminous flux emitted by the power consumed.

symbol η_v, η

unit : lumen per watt (lm.W^{-1})

NOTE — Formerly *luminous efficiency*.

3.10 Luminous Intensity of a Source, in a Given Direction — Quotient of the luminous flux leaving the source, propagated in an element of solid angle containing the given direction, by the element of solid angle.

symbol I_v, I

$$I_v = \frac{d\Phi v}{d\Omega}$$

unit : candela (cd)

NOTE 1 — *See* Note under **2.2.7**.

NOTE 2 — The term *candlepower* designates a luminous intensity expressed in candelas.

3.11 Candela — SI unit of luminous intensity : The magnitude of the candela is such that the luminance of a full radiator at the temperature of solidification of platinum is 60 candelas per square centimetre (9th General Conference of Weights and Measures, 1948).

symbol cd

$1\text{cd} = 1\ \text{lm.sr}^{-1}$

3.12 Mean Spherical (Luminous) Intensity of a Source — Average value of the luminous intensity in all directions.

NOTE — It is also the quotient of the luminous flux by the solid angle 4π steradians.

3.13 (Luminous) Sector Flux — Of a rectilinear source of negligible cross-section, of infinite length, in a direction perpendicular to its axis-quotient of the luminous flux emitted by unit length of the source in the sector included between two planes passing through the source enclosing the given direction and making between them an infinitesimal angle, by that angle.

symbol J

unit : lumen per metre and per radian ($\text{lm.m}^{-1}.\text{rad}^{-1}$)

NOTE — It is presumed that the flux considered in this definition is independent of the part of the source considered.

The illuminance, E, for a plane element normal to the direction and situated at a distance, l, on a perpendicular to the source is $E = J.l^{-1}$. This formula gives an approximation useful in the case where the ends of the source are sufficiently far away from the plane element considered.

3.14 Luminance in a Given Direction — At a point on the surface of a source or a receptor, or at a point on the path of a beam-quotient of the luminous flux leaving, arriving at, or passing through, an element of surface at this point and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone and the area of the orthogonal projection of the element of surface on a plane perpendicular to the given direction.

symbol L_v, L

$$L_v = \frac{d\,\Phi_v}{d\Omega dA.\cos\theta}$$

unit : candela per square metre ($cd.m^{-2}$)

NOTE — Three special cases may be noted.

Case 1 — At a point on the surface of a source, in a given direction, luminance is also the quotient of the luminous intensity in the given direction of an element of the surface at this point, by the area of the orthogonal projection of this element on a plane perpendicular to this direction (luminous intensity per unit projected area).

$$L_v = \frac{dI_v}{dA.\cos\theta}$$

Case 2 — At a point on the surface of a receptor, in a given direction, luminance is also the quotient of the illuminance which is received at this point on a surface perpendicular to the given direction, by the solid angle of the elementary cone containing this direction and illuminance per unit solid angle.

$$L_v = \frac{dE_v}{d\Omega}$$

Case 3 — On the path and in the direction of an element of a beam, in a non-diffusing, non-absorbing medium, the luminance is also the quotient of the luminous flux $d\phi v$ which transports the beam, by the geometric extent dG of the beam. The *geometric extent*, which may be defined by two sections of the beam of areas dA and dA′, of separation and having angle θ and θ' between their normals and the direction of the beam is $dG = dA.\cos\theta.d\Omega$, where the numerical value in steradians of $d\Omega$ is $dA'.\cos\theta'.1^{-2}$.

$$L_v = \frac{d\phi v}{dG} = \frac{d^2\,\phi v}{d\Omega.dA.\cos\theta}$$

In the absence of diffusion, it can be demonstrated in geometrical optics that the *optical extent*, product of the geometric extent of a beam and the s square of the refractive index of the medium of propagation, is an invariant along the length of the beam whatever the deviations which it undergoes by reflection or refraction ($dG.n^2 = \text{constant}$). In consequence, the *basic luminance*, quotient of the luminance by the square of the refractive index, is invariant along the length of a beam except for losses by absorption or by reflection ($Lv.n^{-2} = \text{constant}$).

3.15 Equivalent Luminance of a Field of Given Size and Shape, for a Radiation of Arbitrary Relative Spectral Composition — Luminance of a comparison field in which the radiation has the same spectral composition as that of a full radiator at the temperature of freezing platinum and which has the same luminosity as the field considered under the specified photometric conditions of measurement; the comparison field shall have a specified size and shape which may be different from that of the field considered.

symbol L_{eq}

unit : candela per square metre ($cd.m^{-2}$

NOTE — A comparison field may also be used, in which the radiation has a spectral composition different from that of a full radiator at θ if the equivalent luminance of this field is known under the same conditions of measurement.

3.16 Candela Per Square Metre — SI unit of luminance.

symbol $cd.m^{-2}$

NOTE — This unit is sometimes named *nit*, symbol nt.

Other units of luminance:

metric : stilb (sb) = 10^4 $cd.m^{-2}$

apostilb (asb) = $\frac{1}{\pi}$ $cd.m^{-2}$

lambert (L) = $\frac{10^4}{\pi}$ $cd.m^{-2}$

non-metric : footlambert (fL) = 3·426 $cd.m^{-2}$

3.17 Luminous Flux (Surface) Density at a Point of a Surface — Quotient of the luminous flux at an element of the surface cotaining the point, by the area of that element mathematically expressed as $\frac{d\Phi v}{dA}$.

symbol (*under consideration*)

unit : lumen per square metre ($lm.m^{-2}$)

NOTE — *See also* **3.18** and **3.23**.

3.18 Illuminance (Illumination) at a Point of a Surface — Quotient of the luminous flux incident on an element of the surface containing the point, by the area of that element.

symbol E_v, E

$$E_v = \frac{d\Phi v}{dA}$$

unit : lux (lx)

NOTE — The use of the term 'illumination' for this quantity conflicts with its more general use given in **3.19**.

3.19 Lux, Lumen Per Square Metre — SI unit of illuminance : Illuminance produced by a luminous flux of 1 lumen uniformly distributed over 1 square metre.

symbol lx

$$1\ \mathrm{lx} = \mathrm{Lm.m^{-2}}$$

NOTE — Other units of illuminance:

metric : 1 *phot*.........

non-metric : 1 *footcandle* (fc) or 1 *lumen*.........

3.20 Point Brilliance — Quantity involved in the visual observation of a source of light when viewed directly from such a distance that the apparent diameter is inappreciable. The point brilliance is measured by the illuminance produced by the source on a plane at the observer's eye normal to the direction of the source.

symbol E_v, E

unit : lux (lx)

3.21 Light Exposure — Surface density of the quantity of light received.

symbol H_v, H

$$H_v = \frac{dQv}{dA} = \int E_v dt$$

unit : lux-second (lx.s)

NOTE 1 — Formerly *quantity of illumination*.

NOTE 2 — Equivalent definition : Product of an illuminance and its duration.

3.22 Lux-Second — SI unit of light exposure : Light exposure produced by a quantity of light of 1 lumen-second on an area of 1 square metre.

symbol lx.s

3.23 Luminous Exitance — At a point of a surface the quotient of the luminous flux leaving an element of the surface containing the point, by the area of that element.

symbol M_v, M

$$M_v = \frac{d\Phi v}{dA} \int L_v.\cos\theta.d\Omega$$

unit : lumen per square metre ($\mathrm{lm.m^{-2}}$)

NOTE 1 — Formerly *luminous emittance*. *See also* Note 1 under **2.2.12**.

NOTE 2 — On the use of the adjectives *self* and *thermal*, *see* Note 2 under **2.2.12**.

NOTE 3 — In the case of a full radiator (blackbody) the luminance L_v is uniform in all directions. In consequence, when the solid angle is measured in steradians the luminous exitance has the numerical value $M_v = \pi L_v$.

3.24 Spectral Concentration of a Photometric Quantity: Luminous Flux, Luminous Intensity, etc — Quotient of the quantity, taken over an infinitesimal range on either side of a given wavelength, by the range.

$$X_{v,\lambda} = \frac{dX_v}{d\lambda}$$

Note 1 — Frequencies, wavenumbers or their logarithms may also be used; if there is a risk of ambiguity this should be avoided by means of the wording: 'spectral concentration in terms of frequency'.

Note 2 — *See* **2.2.0.2**.

3.25 Spectral Distribution Curve of a Photometric Quantity: Luminous Flux, Luminous Intensity, etc — Curve representing the spectral concentration of the quantity as a function of wavelength.

Note 1 — *See* Note 1 under **3.24**.

Note 2 — Commonly the *relative spectral distribution curve* is used. That is the curve representing the ratio of the spectral concentration of the quantity to a certain value of the same quantity.

4. COLORIMETRY: FUNDAMENTAL CONCEPTS AND QUANTITIES

4.0 Preliminary Remarks

4.0.1 Many terms, among others 'colour' (**6.25**), may be considered, as in photometry, from the sensory point of view and from the physical point of view; the latter predominates in this clause.

4.0.2 In the distinction which has to be made between quantities which refer to an individual observer and those which refer to the standard colorimetric observer, the importance of the difference between the individual functions and the standard functions is here greater than in photometry. Nevertheless, the rule is the same as in photometry; unless otherwise stated the quantities refer to a standard colorimetric observer: CIE 1931 or CIE 1964.

4.1 Light Stimulus — Radiation of defined physical characteristics, which enters the eye and produces a sensation of light.

4.2 Colour Stimulus — Radiation of given intensity and spectral composition, entering the eye and producing a sensation of colour.

4.3 Colour Stimulus Function — The relative spectral distribution of the colour stimulus.

symbol $\varphi(\lambda)$

Note — For light sources the colour stimulus function is the same as the relative spectral energy distribution $S(\lambda)$ of the source (*see* **2.2.17**). For object colours the colour stimulus function is given by either the product $S(\lambda).\beta(\lambda)$ or $S(\lambda)\cdot\tau(\lambda)$, where $\beta(\lambda)$ is the spectral luminance factor and $\tau(\lambda)$ the spectral transmittance.

4.4 Trichromatic System (Colorimetric System) — System of colour specification based on the possibility of matching a colour stimulus by the additive mixture of three suitably chosen reference stimuli.

4.5 Spectral Tristimulus Values — Tristimulus values, on any given colorimetric system, of the monochromatic components of an equi-energy spectrum. The set of spectral tristimulus values defines the *colour-matching functions* or *colour-matching curves.*

NOTE 1 — Formerly *distribution coefficients.*

NOTE 2 — The symbols used are small letters with a bar followed by the letter λ in parentheses; the letters chosen should correspond with those used for the reference stimuli. Example: Reference stimuli (R), (G), (B); corresponding spectral tristimulus values $r(\lambda)$, $g(\lambda)$, $b(\lambda)$.

4.6 CIE Spectral Tristimulus Values — Tristimulus values of the spectral components of an equi-energy spectrum in the CIE (XYZ) system.

NOTE 1 — Formerly *CIE-distribution coefficients.*

NOTE 2 — In the standard system, applicable to observing fields of angular subtense between 1° and 4°, these tristimulus values $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ are so chosen that the values of $\bar{y}(\lambda)$ are identical with the spectral luminous efficiencies $V(\lambda)$ (*see* Table 2)

NOTE 3 — In the supplementary system, applicable to observing fields of angular subtense greater than 4°, these tristimulus values $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ are so chosen that the values of $\bar{y}_{10}(\lambda)$ are in accord with the spectral luminous efficiencies under photopic conditions with an observing field of angular subtense equal to 10° (*see* Table 3).

TABLE 2 STANDARD COLORIMETRIC OBSERVER CIE 1931*

(*Clause* 4.6)

Spectral Stimulus Values

λ (nm)	$\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$
380	0·001 4	0·000 0	0·006 5
390	0·004 2	0·000 1	0·020 1
760	0·000 2	0·000 1	0·000 0
770	0·000 1	0·000 0	0·000 0

*Abridged version. $\bar{y}(\lambda) = V(\lambda)$ are rounded off to four decimals.

TABLE 3 SUPPLEMENTARY COLORIMETRIC OBSERVER CIE 1964*

(*Clause* 4.6)

Spectral Tristimulus Values

λ (nm)	$\bar{x}_{10}(\lambda)$	$\bar{y}_{10}(\lambda)$	$\bar{z}_{10}(\lambda)$
380	0·000 2	0·000 0	0·000 7
390	0·002 4	0·000 3	0·010 5
760	0·000 1	0·000 0	0·000 0
770	0·000 1	0·000 0	0·000 0

*Abridged version.

4.7 CIE 1931 Standard Colorimetric System — Linear and single-valued colorimetric system for evaluating any spectral distribution of energy with the aid of three functions of wavelength, the CIE spectral tristimulus values : $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$.

4.8 CIE 1964 Supplementary Colorimetric System — Linear and single-valued colorimetric system for evaluating any spectral distribution of energy with the aid of three functions of wavelength, the CIE spectral tristimulus values : $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$.

4.9 CIE 1931 Standard Colorimetric Observer — Receptor of radiation whose colorimetric characteristics correspond to the spectral tristimulus values $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ adopted by the International Commission on Illumination in 1931 (*see* **4.6**).

4.10 CIE 1964 Supplementary Colorimetric Observer — Receptor of radiation whose colorimetric characteristics correspond to the spectral tristimulus values $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ adopted by the International Commission on Illumination in 1964 (*see* **4.6**).

4.11 Tristimulus Values of a Colour Stimulus — Amounts of the three reference or matching stimuli required to give a match with the colour stimulus considered, in a given trichromatic system.

NOTE 1 — The symbols recommended for the tristimulus values are : X, Y, Z in the CIE 1931 standard colorimetric system, and X_{10}, Y_{10}, Z_{10} in the CIE 1964 supplementary colorimetric system.

NOTE 2 — It is recommended that the tristimulus values of object colours be expressed on a scale having a tristimulus value of $Y = 100$ (or $Y_{10} = 100$) for a perfect reflecting diffuser (opaque samples) or a perfectly transparent and non-diffusing filter (non-diffusing transmitting samples), under identical conditions of illumination and observation.

NOTE 3 — The tristimulus values may be obtained by multiplying the colour stimulus function $\varphi(\lambda)$ by the CIE spectral tristimulus values and integrating these products over the whole spectrum:

$$X = \int \varphi(\lambda)\, \bar{x}(\lambda)\, d\lambda \qquad X_{10} = \int \varphi(\lambda)\, \bar{x}_{10}(\lambda)\, d\lambda$$

$$Y = \int \varphi(\lambda)\, \bar{y}(\lambda)\, d\lambda \qquad Y_{10} = \int \varphi(\lambda)\, \bar{y}_{10}(\lambda)\, d\lambda$$

$$Z = \int \varphi(\lambda)\, \bar{z}(\lambda)\, d\lambda \qquad Z_{10} = \int \varphi(\lambda)\, \bar{z}_{10}(\lambda)\, d\lambda$$

4.12 Chromaticity Coordinates — Ratio of each of the three tristimulus values to their sum.

NOTE — The symbols recommended for the chromaticity coordinates are : x, y, z in the CIE 1931 standard colorimetric system, and x_{10}, y_{10}, z_{10} in the CIE 1964 supplementary colorimetric system.

$$x = \frac{X}{X + Y + Z} \qquad x_{10} = \frac{X_{10}}{X_{10} + Y_{10} + Z_{10}}$$

$$y = \frac{Y}{X + Y + Z} \qquad y_{10} = \frac{Y_{10}}{X_{10} + Y_{10} + Z_{10}}$$

$$z = \frac{Z}{X + Y + Z} \qquad z_{10} = \frac{Z_{10}}{X_{10} + Y_{10} + Z_{10}}$$

$$x + y + z = 1 \qquad x_{10} + y_{10} + z_{10} = 1$$

4.13 Isochromatic Stimuli — Colour stimuli which, when acting simultaneously in adjacent fields, give rise to identical colour sensations. The identity of colour may result from the identity of spectral distribution or it can occur when the spectral distributions are different (metameric colour stimuli).

NOTE — In photometry it is usual to describe lights as isochromatic if they have the same chromaticity.

4.14 Heterochromatic Stimuli — Colour stimuli which, when acting simultaneously in adjacent fields, give rise to different colour sensations.

4.15 Matching Stimuli; Instrumental Stimuli — The defined stimuli of an additive colorimeter.

4.16 Reference Stimuli — Colour stimuli, not collinear but otherwise unrestricted, whose additive mixture can be used to evaluate all other colour stimuli. Three reference stimuli are necessary and sufficient for this purpose.

4.17 Basic Stimulus — Standard stimulus (usually achromatic) used to determine the units of the reference stimuli of any trichromatic system.

4.18 Cardinal Stimuli — Four standard stimuli by means of which the three reference stimuli and the basic stimulus of any trichromatic system may be defined. Monochromatic light stimuli of wavelengths 700, 546·1 and 435·8 nm and standard illuminant B have been adopted by CIE in 1931.

4.19 Trichromatic Units — Relative units of stimulus quantity, applicable to any colour stimulus and such that the quantity of any stimulus, when expressed in these units, is equal to the sum of the tristimulus values.

4.20 Chromaticity — Colour quality of a colour stimulus definable by its chromaticity coordinates, or by its dominant (or complementary) wavelength and its purity taken together.

4.21 Chrominance of a Colour Stimulus — Colorimetric difference, between the colour stimulus and a reference stimulus of a given chromaticity and the same luminance, expressible as the product of the chromaticity difference and the luminance.

NOTE — This term is used in the technique of colour television. The reference stimulus is usually achromatic. In colour space, chrominance is a vector in a plane of constant luminance; and the components of this vector are called *chrominance components*. Chrominance relative to an achromatic stimulus is the colorimetric correlate of the psychosensorial concept ‘ chroma ’.

4.22 Dominant Wavelength of a Colour Stimulus, not Purple — Wavelength of the monochromatic light stimulus that, when combined in suitable proportions with the specified achromatic light stimulus, yields a match with the colour stimulus considered.

symbol λd

NOTE — When the dominant wavelength cannot be given (this applies to purples), its place is taken by the complementary wavelength.

4.23 Excitation Purity — Quantity p_e defined by the relations

$$p_e = \frac{y - y_w}{y_d - y_w} \quad \text{or} \quad p_e = \frac{x - x_w}{x_d - x_w}$$

where x and y are the chromaticity coordinates of the colour stimulus considered, x_d and y_d those of the monochromatic light stimulus which has the same dominant wavelength as the colour stimulus considered; x_w and y_w are the chromaticity coordinates or the specified achromatic light stimulus.

NOTE 1 — For colour stimuli for which no dominant wavelength exists the chromaticity coordinates to be taken for x_d and y_d are those of the corresponding point of the purple boundary.

NOTE 2 — Whether the formula in x or that in y is to be taken depends on which gives the numerator the greater numerical value.

NOTE 3 — In the CIE 1964 Supplementary Colorimetric System, the excitation purity $p_{e,10}$ is defined by the same relations in which x_{10} and y_{10} are taken instead of x and y.

4.24 Colorimetric Purity — Quantity p_c defined by the relation

$$p_c = p_e \frac{y_d}{y}$$

where the symbols have the same meanings as in **4.23**.

NOTE — In the CIE 1964 Supplementary Colorimetric System, the colorimetric purity $p_{c,10}$ is defined by the same relation in which $p_{e,10}$ and y_{10} are taken instead of p_e and y.

4.25 Complementary Wavelength of a Colour Stimulus — Wavelength of the monochromatic light stimulus that, when combined in suitable proportions with the colour stimulus considered, yields a match with the specified achromatic light stimulus.

symbol λ_c

4.26 Achromatic — In accepted colorimetric sense:

a) For primary light sources, the colour of the equi-energy spectrum ($x = y = z = 1/3$) is taken as achromatic.

b) For surface colours, the light source serving as illuminant is taken as achromatic.

NOTE — On this basis, an ideal white surface is always defined as achromatic whatever may be the colour of the light.

4.27 Illuminant — Radiant energy with a relative spectral distribution defined over the wavelength range that influences object colour perception.

NOTE — This term is not restricted to this sense, but is a general term used for any kind of light falling on a body or scene, and is also used to refer to the light source itself, including its filters if any.

4.28 CIE Standard Illuminants — The colorimetric illuminants *A*, *B*, *C* and *D* 6 500, defined by CIE in terms of relative spectral energy distribution.

Standard illuminant A, representing the Planckian radiator to 2 854°K.

Standard illuminant B, representing direct sunlight with a correlated colour temperature of 4 870°K.

Standard illuminant C, representing daylight with a correlated colour temperature of 6 770°K.

Standard illuminant D 6 500, representing daylight with a correlated colour temperature of 6 500°K.

4.29 CIE Standard Sources — The artificial sources specified and recommended by CIE to represent the CIE standard illuminants *A*, *B* and *C*

Standard source A — Gas-filled tungsten filament lamp operating at a correlated colour temperature of 2 854°K.

Standard source B — Source A combined with a specified liquid filter, to give a radiation of a correlated colour temperature of 4 870°K.

Standard source C — Source A combined with a specified liquid filter, to give a radiation of a correlated colour temperature of 6 770°K.

4.30 Specified Achromatic Light Stimulus — Any specified illuminant capable of being accepted as white under usual conditions of observation.

NOTE — This includes the CIE standard illuminants.

4.31 Equi-Energy Spectrum — Spectrum in which the spectral concentration of energy evaluated on a wavelength basis is constant throughout the visible region $S(\lambda) = \text{constant}$.

4.32 Additive Mixture of Colour Stimuli — Mixture of colour stimuli acting in such manner that they enter the eye simultaneously or in rapid succession and are incident on the same area of the retina, or are incident in the form of a mosaic which the eye cannot resolve.

4.33 Colour Equation — Algebraic or geometrical representation of the match of two stimuli, of which, for instance, one may be the result of an additive mixture.

$$C\,(C) = R\,(R) + G\,(G) + B\,(B)$$

4.34 Colour Space — Manifold of three dimensions for the geometrical representation of colours.

4.35 Uniform Colour Space — Colour space in which the distance between any two colour points is intended to represent a measure of the perceived difference between the corresponding colours.

4.36 CIE 1964 Uniform Colour Space — The uniform colour space produced by plotting in rectangular coordinates U *, V * and W *, where

$$U^* = 13\,W^*\,(u - u_0)$$

$$V^* = 13\,W^*\,(v - v_0)$$

$$W^* = 25\,Y^{\frac{1}{3}} - 17 \qquad (1 \leqslant Y \leqslant 100 \text{ (\textit{see} Note 3 under \textbf{4.11}) }$$

u, v are defined in **4.41**, and u_0, v_0 are values of these variables for the nominally achromatic colour.

NOTE 1 — For object colours the choice of the coordinates of the illuminant for u_0, v_0 is satisfactory.

NOTE 2 — In this system the measure ΔE of the perceptual size of the difference between colour (U^*_1, V^*_1, W^*_1) and colour (U^*_2, V^*_2, W^*_2) is:

$$\Delta E = [(U^*_1 - U^*_2)^2 + (V^*_1 - V^*_2)^2 + (W^*_1 - W^*_2)^2]^{\frac{1}{2}}$$

4.37 Colour Solid — That part of colour space which is occupied by surface colours.

4.38 Colour Axis — Line in any three-dimensional representation of a colour system which denotes the direction of one of the reference stimuli.

4.39 Chromaticity Diagram; Colour Triangle — Plane diagram showing the result of mixtures of colour stimuli, each chromaticity being represented unambiguously by a single point on the diagram.

4.40 Uniform-Chromaticity-Scale (UCS) Diagram — Chromaticity diagram in which the coordinate scales are chosen with the intention of making equal intervals represent as nearly as possible equal steps of discrimination for colours of the same luminance at all parts of the diagram.

4.41 CIE 1960 UCS Diagram — The uniform-chromaticity-scale diagram produced by plotting in rectangular coordinates v against u, where

$$v = \frac{6\,Y}{X + 15\,Y + 3\,z}$$

$$u = \frac{4\,x}{x + 15\,Y + 3\,z}$$

4.42 Colour Atlas — Collection of colour samples used for evaluating colours by visual matching.

4.43 Colour Matching — Action of making a colour appear the same as a given colour.

4.44 Spectrum Locus — The line (surface) in a chromaticity diagram (colour space) containing the spectral stimuli.

4.45 Purple Boundary — The line (plane) in a chromaticity diagram (colour space) joining the ends of the spectrum locus.

4.46 Colour Gamut — An area (volume) in a chromaticity diagram (colour space). Usually that part of the chromaticity diagram (colour space) embracing all colours capable of being reproduced by a particular choice or parameters in a colour process.

4.47 Achromatic Locus — The area in a chromaticity diagram embracing all colours capable of being accepted as white under given conditions of observation.

4.48 Planckian Locus — The line in a chromaticity diagram representing full radiators of different temperatures.

4.49 Alychne — Plane in colour space representing the locus of colours of zero luminance. This plane passes through the black point (usually the origin of the system). It intersects any linear chromaticity diagram in a straight line which is also called 'alychne' and lies wholly outside the domain of real chromaticities.

4.50 Additive Complementary Colours — Two colour stimuli are complementary when it is possible to reproduce a specified achromatic stimulus by a suitable additive mixture of these two stimuli.

4.51 Metameric Colour Stimuli; Metamers — Spectrally different radiations that produce the same colour under the same viewing conditions.

NOTE — The corresponding property is called *metamerism*.

4.52 Correlated Colour Temperature — The colour temperature corresponding to the point on the Planckian locus which is nearest to the point representing the chromaticity of the illuminant considered on an agreed uniform-chromaticity-scale diagram.

Unit : degree Kelvin (°K)

NOTE — The presently agreed uniform-chromaticity-scale diagram is the CIE 1960 UCS diagram (*see* **4.41**).

5. OPTICAL PROPERTIES OF MATTER

5.1 Regular (Specular) Reflection — Reflection without diffusion in accordance with the laws of optical reflection.

5.2 Diffuse Reflection — Diffusion by reflection in which, on the macroscopic scale, there is no regular reflection.

5.3 Mixed Reflection — Partly regular and partly diffuse reflection.

NOTE — The irradiance or illuminance received from a point source, after regular (diffuse) reflection, varies inversely as the square of the distance to the source (diffuser).

5.4 Uniform Diffuse Reflection — Diffuse reflection in which the spatial distribution of the reflected radiation is such that the radiance or luminance is the same in all directions in which the radiation is reflected.

5.5 Retro-Reflection; Reflex Reflection — Reflection in which light is returned in directions close to the direction from which it came, this property being maintained over wide variations of the direction of the incident light.

5.6 Reflectance/Reflection Factor — Ratio of the reflected radiant or luminous flux to the incident flux.

symbol ρ_e', ρ_v'

$$\rho = \rho_r + \rho_d$$

NOTE 1 — Where mixed reflection (**5.3**) occurs, the (total) reflectance may be divided into two parts, *regular reflectance* (ρ_r) and *diffuse reflectance* (ρ_d), corresponding respectively to the two modes of reflection referred to in definitions **5.1** and **5.2**.

In general, the values of the various reflectances depend upon the mode of irradiation, the spectral composition and the state of polarization of the incident radiation.

NOTE 2 — On the use of the adjective ' spectral ', *see* **2.2.0.2**.

5.7 Reflectivity — Reflectance of a layer of material of such a thickness that there is no change of reflectance with increase in thickness.

symbol ρ_∞

5.8 Reflection (Optical) Density — Logarithm to base ten of the reciprocal of the reflectance.

symbol D

$$D = -\log_{10} \rho$$

5.9 Regular (Direct) Transmission — Transmission without diffusion.

5.10 Diffuse Transmission — Transmission in which diffusion occurs independently, on the macroscopic scale, of the laws of refraction.

5.11 Mixed Transmission — Partly regular and partly diffuse transmission.

NOTE — The irradiance or illuminance received from a point source, after regular (diffuse) transmission, varies inversely as the square of the distance to the source (diffuser).

5.12 Uniform Diffuse Transmission — Diffuse transmission in which the spatial distribution of the transmitted radiation is such that the radiance or luminance is the same in all directions, in which the radiation is transmitted.

5.13 Transmittance/Transmission Factor — Ratio of the transmitted radiant or luminous flux to the incident flux.

symbol τ_e', τ_v', τ

$$\tau = \tau_r + \tau_d$$

Note 1 — Where mixed transmission (**5.11**) occurs, the (total) transmittance may be divided into two parts, *regular transmittance* (τ_r) and *diffuse transmittance* (τ_d), corresponding respectively to the two modes of transmission referred to in definitions **5.9** and **5.10**.

In general, the values of the various transmittances depend upon the mode of irradiation, the spectral composition and the state of polarization of the incident radiation.

Note 2 — On the use of the adjective ' spectral ', *see* **2.2.0.2**.

5.14 Internal Transmittance of a Homogeneous Non-diffusing Plate — Ratio of the radiant or luminous flux reaching the exit surface of the plate to the flux which leaves the entry surface.

symbol τ_1

Note — The internal transmittance depends on the angle of incidence. The fundamental concept is ' spectral internal transmittance ' $\tau_i (\lambda)$.

5.15 Transmissivity of an Absorbing Material — Internal transmittance of a layer of the material such that the path of the radiation is of unit length, and under conditions in which the boundary of the material has no influence.

5.16 Transmission (Optical) Density — Logarithm to base ten of the reciprocal of the transmittance.

symbol D

$$D = -\log_{10}\tau$$

5.17 Internal Transmission Density — Logarithm to base ten of the reciprocal of the internal transmittance.

symbol D_i

$$D_i = -\log_{10}\tau_i = \log_{10}\frac{1}{\tau_i}$$

Note — *See* Note under **5.14**.

5.18 Absorption Coefficient/Extinction Coefficient — Difference between the logarithm to base 10 of the internal transmission density and 1.

symbol $(\mathrm{H})\ (\lambda)$

$$(\mathrm{H})\ (\lambda) = 1 - \log D_i\ (\lambda) = \log\frac{10}{D_i\ (\lambda)}$$

5.19 Absorptance/Absorption Factor — Ratio of the absorbed radiant or luminous flux to the incident flux.

symbol α_e', α_v', α

NOTE 1 — In general, the value of the absorptance depends upon the mode of irradiation, the spectral composition and the state of polarization of the incident radiation.

NOTE 2 — On the use of the adjective ' spectral ', *see* **2.2.0.2**.

5.20 Internal Absorptance of a Homogeneous Non-diffusing Plate— Ratio of the radiant or luminous flux absorbed between the entry and exit surfaces of the plate to the flux which leaves the entry surface.

symbol α_i

$$\alpha_i + \tau_i = 1$$

NOTE — The internal absorptance depends on the angle of incidence. The fundamental concept is ' spectral internal absorptance ' $\alpha_i(\lambda)$.

5.21 Absorptivity of an Absorbing Material — Internal absorptance of a layer of the material such that path of the radiation is of unit length, and under conditions in which the boundary of the material has no influence.

5.22 Linear Attenuation (Extinction) Coefficient of an Absorbing and Diffusing Medium for a Collimated Beam of Radiation— Quotient of the relative decrease in spectral concentration of the radiant or luminous flux of a collimated beam of radiation during traversal with normal incidence of an infinitesimal layer of the medium, by the thickness dl of that layer.

symbol μ $\quad -d\phi = \mu\phi\, dl$

unit : m^{-1}

NOTE 1 — This concept only applies strictly to slightly diffusing media.

NOTE 2 — μ/ρ, where ρ is the density of the medium, is called *mass attenuation coefficient*.

5.23 Linear Absorption Coefficient of an Absorbing Medium — Quotient of the internal absorptance of a path element traversed by the radiation, by the length dl of this element.

symbol a

$$-d\Phi = a\,\Phi\, dl$$

$$a\,l = \log_e 10\, D_i$$

unit : m^{-1}

NOTE 1 — The linear absorption coefficient is also the part of the linear attenuation coefficient that is due to absorption.

NOTE 2 — a/ρ, where ρ is the density of the medium, is called *mass absorption coefficient*.

5.24 Filter — Device which is used to modify by transmission the radiant or luminous flux, the spectral distribution, or both, of the radiation passing through it.

> NOTE — A distinction is made between *selective* filters and *non-selective* (*neutral*) (*Neutral Grey*) filters according as they do or do not alter ther elative spectral distribution of the radiation. Selective filters are *grey* or *coloured* according to appearance; usually filters appear grey or coloured according as the chromaticity coordinates of the filtered radiation are nearly the same (by metamerism) different from those of the incident radiation.

5.25 Neutral Wedge — Non-selective filter the transmittance of which changes continuously along a path (straight or curved) on its surface.

5.26 Neutral Step Wedge — Non-selective filter in which the transmittance changes by steps along a path (straight or curved) on its surface.

5.27 Transparent Body — Body in which the light transmission is mainly regular and which has a high regular transmittance. Objects are seen distinctly through such a body if its geometrical form is suitable.

5.28 Translucent Body — Body which transmits light principally by diffuse transmission. Objects are not seen distinctly through such a body.

5.29 Opaque Body — Body which transmits practically no light.

5.30 Coloured Body — Body for which the spectral transmittance or reflectance varies with wavelength in the visible region of radiation.

5.31 Uniform Diffusion — Ideal diffusion in which the spatial distribution of diffused radiation is such that the radiance of luminance is the same in all directions.

5.32 Diffuser — Device used to alter the spatial distribution of a radiant or luminous flux and depending essentially on the phenomenon of diffusion.

> NOTE 1 — A distinction is made between *selective diffusers* and *non-selective diffusers* according as their diffusing properties depend on the wavelength of the incident radiation or not.

> NOTE 2 — If all the radiation reflected or transmitted by the diffuser is diffused, so that no radiation directed according to the laws of geometrical optics is present, the diffuser is said to be *completely diffusing*, independently of whether the reflected or transmitted radiation is uniformly distributed in space or not.

5.33 Uniform Diffuser — Diffuser producing uniform diffusion.

5.34 Perfect Reflecting (Transmitting) Diffuser — Ideal uniform diffuser with a reflectance (transmittance) equal to 1.

5.35 Diffusion Factor of a Diffusing Surface by Reflection or by Transmission — Ratio of the mean of the values of luminance measured at 20° and 70° to the luminance measured at 5° from the normal, when the surface considered is illuminated normally.

symbol σ

$$\sigma = \frac{L(20) + L(70)}{2L(5)}$$

NOTE 1 — The diffusion factor is intended to give an indication of the spatial distribution of the diffused flux. It is equal to 1 for every uniform diffuser, whatever the value of the diffuse reflectance.

NOTE 2 — This way of defining the diffusion factor can only be applied to materials for which the indicatrix of diffusion does not differ appreciably from that of ordinary depolished and opal glasses.

5.36 Half-Value Angle for a Diffusing Surface by Reflection or by Transmission — Angle of observation at which the luminance has half the value of the luminance of the diffused light at the angle of 0°, with perpendicular incidence of light.

symbol Υ

NOTE — For the indication of the shape of the indicatrix of diffusion it is recommended to use, in the case of strongly diffusing materials, the diffusion factor Σ and in the case of poorly diffusing materials the half-value angle γ.

5.37 Indicatrix of Diffusion — Representation in space, in the form of a surface expressed in polar coordinates, of the angular distribution of (relative) luminous intensity or of (relative) luminance of an element of surface of a body which diffuses by reflection or by transmission.

NOTE 1 — In many cases only a meridian section of this indicatrix is required.

NOTE 2 — The term indicatrix is often used to denote, instead of the surface, the curve obtained in a similar manner in a plane normal to the element concerned.

NOTE 3 — In the case of a narrow beam of radiation it is convenient to represent the indicatrix of diffusion in Cartesian coordinates.

5.38 Refractive Index of a Medium, for a Monochromatic Radiation of Wavelength λ — Ratio of the velocity of the electromagnetic waves in vacuum to the phase velocity of the waves of the monochromatic radiation in the medium.

symbol $n(\lambda)$

NOTE — This index is equal to the ratio of the sines of the angles of incidence (θ_1) and refraction (θ_2) when a ray crosses the surface separating vacuum and medium

$$n = \frac{\sin \theta_1}{\sin \theta_2}$$

5.39 Radiance (Luminance) Factor, at a Point on the Surface of a Non-self-radiating Body, in a Given Direction, Under Specified Conditions of Irradiation (Illumination) — Ratio of the radiance (luminance) of the body to that of a perfect reflecting or transmitting diffuser identically irradiated (illuminated).

symbol βe, βv, β

5.40 Reflectance Factor at a Point of a Surface, for the Part of the Reflected Radiation Contained in a Given Cone, and for Incident Radiation of Given Spectral Composition and Geometrical Distribution — Ratio of the radiant or luminous flux reflected in the directions delimited by the cone to that reflected in the same directions by a perfect reflecting diffuser identically irradiated (illuminated).

NOTE — If the solid angle of the cone approaches zero, or 2πsr, the reflectance factor approaches radiance or luminance factor, or reflectance, respectively. In instruments called ' reflectance spectro-photometers ' the geometrical distribution is in general intermediate between these two extreme cases. The readings of these instruments, corrected for photometric-scale errors, wavelength-scale errors, and for deviations of the reflecting standard used from a perfect reflecting diffuser, are *spectral* reflectance factor. For a given sample, these values depend on the geometrical characteristics of the instrument.

6. EYE AND VISION

6.1 Organ of Vision/Visual Organ — The group of structures comprising the eye, the optic nerve and certain parts of the brain, which transforms the light stimulus into a complex of nerve excitations, whose subjective correlate is visual perception.

6.2 Eye — Part of the organ of vision, in which an optical image of the external world is produced and transformed into nerve excitations.

6.3 Pupil — Variable aperture in the iris, through which the rays producing the image enter the eye.

6.4 Retina — Membrane at the back of the eye which is sensitive to light stimuli and composed of photoreceptors, the so called cones and rods, and of nerve cells which transmit to the optic nerve the stimulation of the receptor elements.

6.5 Yellow Spot/Macula Lutea — Central part of the retina, containing a yellow pigment.

6.6 Fovea — Central part of the yellow spot, thinner and hence depressed, containing almost exclusively cones and forming the site of most distinct vision. It corresponds to a region of the external field 1° to 2° in diameter.

6.7 Adaptation

a) The process by which the properties of the organ of vision are modified according to the luminances or the colour stimuli presented to it.

b) The final state of the process. In particular, the terms light adaptation and dark adaptation are used, according as the luminance is of at least several candelas per square metre, or less than some hundredths of a candela per square metre (*see also* **6.11** and **6.12**).

6.8 Cones — Special retinal receptor elements which are presumed to be primarily concerned with perception of light and colour stimuli when the eye is adapted to light (*see* photopic vision **6.11**).

6.9 Rods — Special retinal receptor elements which are presumed to be primarily concerned with perception of light stimulus when the eye is adapted to darkness.

NOTE — The rods probably play no part in colour stimulus discrimination (*see* scotopic vision **6.12**).

6.10 Vision — The appreciation of differences in the external world, resulting from the sensory impressions produced by radiation entering the eye.

NOTE — Vision = *visual perception.*

6.11 Photopic Vision — Vision by the normal eye when adapted to levels of luminance of at least several cd/m^{-2}.

NOTE — The cone receptors of the retina are considered to be the principal active elements under these conditions and the spectrum appears coloured.

6.12 Scotopic Vision — Vision by the normal eye when adapted to levels of luminance below some hundredths of a candela per square metre.

NOTE — The rod receptors in the retina are considered to be the principal active elements under these conditions.

The spectrum appears uncoloured and the maximum luminous efficiency is shifted to a shorter wavelength than in photopic vision.

6.13 Mesopic Vision — Vision intermediate between photopic and scotopic vision.

6.14 Spectral Luminous Efficiency for an Individual Observer, for a Monochromatic Radiation of Wavelength λ — Ratio of the radiant flux at wavelength λ_m to that wavelength λ, when by means of suitable experimental apparatus these can be judged equal in luminosity, the judgement being based either on visual equivalence or on the disappearance of some phenomenon, which indicates a difference in the case of other ratios.

NOTE — For spectral luminous efficiency for the standard photometric observer, for photopic vision and for scotopic vision, *see* **3.2**.

6.15 Purkinje Phenomenon — Reduction in the luminosity of a red light relative to that of a blue light when the luminances are reduced in the same proportion without changing the respective spectral distributions.

NOTE — In passing from photopic to scotopic vision, the spectral luminous efficiencies change, the wavelength of maximum efficiency being displaced towards the shorter wavelengths.

6.16 Besold-Brucke Phenomenon — Change in the hue of the (perceived) colour with change in luminance level within the range of photopic vision.

6.17 Stiles-Crawford Effect — Variation of the luminosity of a light stimulus with position of entry of the light pencil through the pupil.

6.18 Troland — Unit used for expressing the magnitude of the external light stimulus applied to the eye. When the eye is viewing a surface of uniform luminance, the number of trolands is equal to the product of the area in square millimetres of the limiting pupil, natural or artificial, and the luminance of the surface in candelas per square metre.

NOTE — In computing retinal illuminance, absorption and reflection losses and the dimensions of the particular eye under consideration shall be taken into account. An allowance shall also be made for the Stiles-Crawford effect if any part of the bundle of rays passes through the pupil in an area significantly separated from its centre. This allowance for the Stiles-Crawford effect may be expressed by a generally lower number of reduced trolands, computed by multiplying the number of trolands by appropriate factors which reach, for example, the value of 0·5 for a pupil of 50 mm^2 area (8 mm diameter).

If all these corrections are negligible, 1 troland produces a retinal illuminance of approximately 2×10^{-3} lumen per square metre.

6.19 Perception — Complex appearing in the field of consciousness and made of sense impressions supplemented by the memory. Visual perceptions, in particular, contribute towards the formation of our concepts of the existence, form and position of objects.

6.20 Speed of Perception — Reciprocal of the time interval between the instant at which an object is presented and the perception of its form.

6.21 Sensation — Element of the mental content of a sense impression which cannot be analysed further.

6.22 Speed of Sensation of Light Stimulus — Reciprocal of the time interval between the onset of a light stimulus and the initiation of the visual sensation it produces.

NOTE — The time interval referred to is also designated as the *latency time.*

6.23 Speed of Contrast Perception — Reciprocal of the time interval between the instant at which a contrast is presented and the instant at which it is perceived.

6.24 Light — Attribute of all the perceptions or sensations which are peculiar to the organ of vision and which are produced through the agency of that organ.

Radiation capable of stimulating the organ of vision.

6.25 Colour

6.25.1 (*Perceived*) *Colour* — Aspect of visual perception by which an observer may distinguish differences between two fields of view of the same size, shape and structure, such as may be caused by differences in the spectral composition of the radiation concerned in the observation.

6.25.2 (*Psychophysical*) *Colour* — Characteristic of a visible radiation by which an observer may distinguish differences between two fields of view of the same size, shape and structure, such as may be caused by differences in the spectral composition of the radiation concerned in the observation.

Note 1 — Psychophysical colour is specified by the tristimulus values of the radiation entering the eye (*see* **4.11**)

Note 2 — The adjectives ' perceived ' and ' psychophysical ' shown in parentheses are necessary only when the context does not clearly indicate whether the terms are used in the subjective or objective sense.

6.26 (Perceived) Chromatic Colour — Perceived colour possessing a hue.

Note — In everyday speech the word ' colour ' is often used in this sense in contradistinction to white, black, or grey. The adjective ' coloured ' usually refers to chromatic colour.

6.27 (Psychophysical) Chromatic Colour — Psychophysical colour of greater than zero purity and hence possessing a dominant or complementary wavelength.

6.28 (Perceived) Achromatic Colour — Perceived colour devoid of hue.

6.29 (Psychophysical) Achromatic Colour — Psychophysical colour of zero purity (*see* **4.26**).

6.30 Colour Vision — Ability of an observer to perceive chromatic colours.

6.31 Unrelated (Perceived) Colour — Colour perceived to belong to an area with completely dark surroundings.

Note — The colour appears self-luminous.

6.32 Related (Perceived) Colour — Colour perceived to belong to an area or object in relation to other perceived colours in the visual field.

6.33 Non-self-luminous (Perceived) Colour [(Perceived) Surface Colour)] — Colour perceived to belong to a non-self-luminous object.

6.34 Self-luminous (Perceived) Colour — Colour perceived to belong to a self-luminous area or object.

Note 1 — To obtain such a perceived colour usually requires the colour to be surrounded by other perceived colours all of considerably lower luminosity.

Note 2 — If the surroundings are completely dark, the self-luminous colour becomes an unrelated colour.

6.35 Non-object (Perceived) Colour; Aperture Colour — Colour perceived as non-located in depth as that perceived as filling a hole in a screen.

6.36 (Perceived) Object Colour — Colour of an object perceived either as self-luminous or non-self-luminous.

6.37 Luminosity — Attribute of visual sensation according to which an area appears to emit more or less light.

Note 1 — In practice, the term ' brightness ' is now reserved to describe ' brightness of colour ' (that is, the opposite of ' dullness ') as used in the dyeing industry.

Note 2 — This attribute is the psychosensorial correlate (or nearly so) of the photometric quantity ' luminance '.

6.38 Hue — Attribute of visual sensation which has given rise to colour names, such as : blue, green, yellow, red, purple, etc.

Note — This attribute is the psychosensorial correlate (or nearly so) of the colorimetric quantity ' dominant wavelength '.

6.39 Saturation — Attribute of a visual sensation which permits a judgement to be made of the proportion of pure chromatic colour in the total sensation.

Note 1 — This attribute is the psychosensorial correlate (or nearly so) of the colorimetric quantity ' purity '.

Note 2 — *See* Note under **6.42**.

6.40 Lightness — Attribute of visual sensation in accordance with which a body seems to transmit or reflect diffusely a greater or smaller fraction of the incident light.

Note — This attribute is the psychosensorial correlate (or nearly so) of the photometric quantity ' luminance factor '.

6.41 Chromaticness — Attribute of a visual sensation combining the hue and the saturation.

Note — This attribute is the psychosensorial correlate (or nearly so) of the colorimetric quantity ' chromaticity '.

6.42 Chroma — Attribute of a visual sensation which permits a judgement to be made in the amount of pure chromatic colour present, irrespective of the amount of achromatic colour.

Note — For colours of the same luminosity and hue, equal sensation intervals of saturation and chroma are identical. In a series of perceived colours of constant saturation, the chroma increases with the luminosity. This attribute is the psychosensorial correlate (or nearly so) of the colorimetric quantity ' chrominance '.

6.43 State of Chromatic Adaptation — Condition of the eye in equilibrium with the totality of colours of the visual field.

6.44 Change of Chromatic Adaptation — Act of changing the state of chromatic adaptation.

6.45 Night-Blindness; Hemeralopia — Anomaly of vision in which there is a pronounced inadequacy or complete absence of dark-adaptation.

6.46 Defective Colour Vision — Marked departure of the individual spectral tristimulus values from those of the standard colorimetric observer (whose vision is taken as normal colour vision).

Note — The following are the types usually recognized:

anomalous trichromatic vision, or *anomalous trichromatism*;

dichromatic vision, or *dichromatism* (partial colour blindness);

monochromatic vision, or *monochromatism* (total colour blindness, anomaly of colour vision in which there is perception of luminance but not of colour).

Both anomalous trichromatism and dichromatism occur in three distinct forms called respectively *protanomalous vision* and *protanopia*, *deuteranomalous vision* and *deuteranopia*, *tritanomalous vision* and *tritanopia*.

6.47 Visual Field of the Eye or Eyes — Angular extent of the space in which an object can be perceived when the head and the eye (or eyes) are at rest. The field may be monocular or binocular.

6.48 Visual Acuity; Sharpness of Vision

6.48.1 *Qualitatively* — Capacity for seeing distinctly object very close together.

6.48.2 Reciprocal of the value (generally in minutes of arc) of the angular separation of two neighbouring objects (points or lines) which the eye can just see as separate.

6.49 Accommodation — Adjustment of the eye, generally spontaneous, made for the purpose of looking at an object situated at a given distance.

6.50 Absolute Threshold of Luminance — Smallest luminance perceptible.

6.51 Luminance Difference Threshold — Smallest difference of luminance perceptible.

symbol ΔL

6.52 Contrast

a) *Subjective Sense* — Subjective assessment of the difference in appearance of two parts of a field of view seen simultaneously or successively. (Hence : luminosity contrast, lightness contrast, colour contrast, simultaneous contrast, successive contrast).

b) *Objective Sense* — Quantities defined by the following formulae (for the case of *luminance contrast*):

a) $$\frac{L_2 - L_1}{L_1}$$

b) $\dfrac{L_2 - L_1}{\frac{1}{2}(L_2 + L_1)}$

c) $\dfrac{L_2}{L_1}$

NOTE — Example (c) is better known as *luminance ratio.*

6.53 Contrast Sensitivity — S Reciprocal of the minimum relative luminance difference perceptible.

symbol S_0

$$S_0 = \frac{L}{\Delta L}$$

6.54 Flicker — Impression of fluctuating luminance or colour, occurring when the frequency of the variation of the light stimulus lies between a few hertz and the fusion frequency of the images.

6.55 Fusion Frequency — Frequency of succession of retinal image above which their differences of luminosity or colour are no longer perceptible.

6.56 Talbot's Law — If a point of the retina is excited by a light stimulus whose photometric value undergoes periodic variations at a frequency exceeding the fusion frequency, the visual sensation produced is identical with that obtained from stimulus emitted equal to the mean value of the variable stimulus over a period.

6.57 Amplitude of Fluctuation of the Luminous Intensity of a Source Run on Alternating Current — Relative amplitude of the periodic fluctuation of luminous intensity as measured by the ratio of the difference between the maximum and the minimum luminous intensity, to the maximum value.

$$\frac{I_{max} - I_{min}}{I_{max}}$$

6.58 Unsteadiness of the Light Emitted by a Source — Irregular or slowly periodic fluctuations of the luminous intensity.

NOTE — These fluctuations are unrelated to the frequency of the electrical supply if the source is fed by alternating current.

6.59 Stroboscopic Effect — Apparent change of motion or immobilization of an object when the object is illuminated by a periodically varying light of appropriate frequency.

6.60 Glare — Condition of vision in which there is discomfort or a reduction in the ability to see significant objects, or both, due to an unsuitable distribution or range of luminance or to extreme contrasts in space or time.

6.61 Disability Glare — Glare which impairs the vision of objects without necessarily causing discomfort.

6.62 Discomfort Glare — Glare which causes discomfort without necessarily impairing the vision of objects.

6.63 Direct Glare — Glare due to a luminous object situated in the same or nearly the same direction as the object viewed (*see also* **6.65**).

6.64 Indirect Glare — Glare due to a luminous object situated in a direction other than that of the object viewed.

6.65 Reflected Glare — Glare produced by the specular reflection originating from luminous objects, particularly when the reflected images appear in the same direction as the object viewed, or in a near-by direction.

NOTE — Commonly this concept includes also other ill effects, such as deterioration of contrasts.

6.66 Equivalent Veiling Luminance — Luminance which has to be added to the adapting background luminance in order to make the luminance difference threshold in the absence of disability glare the same as that experienced in the presence of disability glare.

6.67 Colour Rendering — General expression for the effect of an illuminant on the colour appearance of objects in conscious or subconscious comparison with their colour appearance under a reference illuminant.

6.67.1 *Colour Rendering Properties* — Effect of a light source on the colour appearance of objects in comparison with their colour appearance under a reference illuminant for specified conditions.

6.67.2 *Colour Rendering Index of a Light Source* — Measure of the degree to which the perceived colours of objects illuminated by the source conform to those of the same objects illuminated by a reference illuminant for specified conditions.

NOTE — *Special colour rendering index* is restricted to a particular object (or a group of objects of which the particular object is an adequate representative). General colour rendering index refers to a group of diverse objects.

6.67.3 *Colorimetric Shift* — Change of chromaticity and luminance factor of colour of an object due to change of the illuminant.

6.67.4 *Adaptive Colour Shift* — The change in the perceived colour of an object caused solely by change of chromatic adaptation.

6.67.5 *Resultant Colour Shift* — Difference between the perceived colour of an object illuminated by a test source and that of the same object illuminated by the reference illuminant, taking account of the state of chromatic adaptation in each case. (Resultant of colorimetric shift and adaptive colour shift.)

7. RADIOMETRIC, PHOTOMETRIC AND COLORIMETRIC MEASUREMENTS : PHYSICAL RECEPTORS

7.1 **Primary Standard of Light** — Standard light source reproducible from a specification by which the unit of light is established.

Note — The present international standard is a full radiator at the temperature of freezing platinum.

7.2 **Secondary Standard of Light** — Constant and reproducible light source, the luminous intensity (or the luminous flux or the luminance) of which has been determined directly or indirectly by comparison with the primary standard.

7.3 **Working Standard of Light** — Light source in regular use which is calibrated from time to time by reference to a secondary standard.

7.4 **Comparison Lamp** — Light source having constant, but not necessarily known, luminous intensity, with which a standard lamp and the light source under test are successively compared.

7.5 **Radiometry** — Measurement of the quantities associated with radiation.

7.6 **Radiometer** — Instrument for measuring radiation in energy or power units.

7.7 **Spectroradiometer** — Instrument for measuring the spectral concentration of radiant energy or radiant power.

7.8 **Spectrophotometer** — Instrument for measuring the ratio of two spectral radiometric quantities.

7.9 **Colorimetry** — Measurement of colours, made possible by the properties of the eye and based on a set of conventions.

7.10 **Colorimeter** — Instrument for measuring the tristimulus values or the chromaticity coordinates of a colour stimulus.

Note — This term, or the term *photocolorimeter*, sometimes also covers simplified spectrophotometers for measuring spectral transmittance or reflectance with substantially monochromatic radiation isolated by means of selective filters.

7.11 **Photometry** — Measurement of quantities referring to radiation evaluated according to the visual effect which it produces, as based on certain conventions.

7.12 **Visual Photometry (Colorimetry)** — Photometry (colorimetry) in which the eye is used to make the comparison.

Note — In photometry the methods of comparison chiefly employed are : luminosity match of two adjacent surfaces, adjustment to equality of contrast, or adjustment to minimum flicker.

7.13 Physical Photometry (Colorimetry) — Photometry (colorimetry) in which physical receptors are used to make the measurements.

7.14 Photometer — Instrument for measuring photometric quantities.

7.15 Visual Photometer (Colorimeter) — Photometer in which equality between radiation under test and comparison radiation is established visually.

7.16 Physical Photometer (Colorimeter) — Photometer (colorimeter) in which a physical receptor of radiation is used.

7.17 Photometer Bench — Bench designed to support a photometer head and lamps in such a way that the distances between the lamps and the head may be readily altered and measured.

7.18 Integrating Photometer — Apparatus which enables luminous flux to be determined by a single comparison. The most commonly used form of integrating photometer is the Ulbricht sphere with associated photometric equipment.

7.19 Integrating (Ulbricht) Sphere — Part of an integrating photometer. A sphere which is coated internally with a white diffusing paint as non-selective as possible which is provided with an associated equipment for making a photometric measurement at a point of the inner surface of the sphere. A screen placed inside the sphere prevents the point under observation from receiving any radiation directly from the source.

7.20 Flicker Photometer — Visual photometer in which the eye sees an undivided field illuminated alternately by two sources to be compared, the frequency of alternation being conveniently chosen so that it is above the fusion frequency for colours but below the fusion frequency for luminosities.

7.21 Equality of Luminosity (Equality of Contrast) Photometer — Visual photometer in which the parts of the comparison field are viewed simultaneously and are adjusted to equality of luminosity (of contrast).

7.22 Photometer Head — The part of a visual photometer in which photometric comparison is effected, or the part of a physical photometer containing the receptor.

7.23 Photometer Test Plate — Plate, having known properties for photometric purposes, which is illuminated by the light under test.

7.24 Comparison Surface of a Visual Photometer — Surface, the luminosity of which is compared visually with the luminosity of some other surface.

7.25 Surround of a Comparison Field — Area which immediately surrounds the field in which a photometric (colorimetric) comparison is being made, its luminosity affecting the result of the matching only in so far as it may affect the visual organ.

7.26 Photoelectric Photometer (Colorimeter) — Particular type of physical photometer using photoelectric receptor.

7.27 Illumination Photometer or Footcandle Meter — Instrument for the measurement of illuminance.

7.28 Luminance Meter — Instrument for the measurement of luminance.

7.29 Reflectometer — Instrument for the measurement of quantities pertaining to reflection.

7.30 Densitometer — Photometer for measuring reflection or transmission density.

7.31 Exposure Meter — Light-measuring instrument for ascertaining the setting (lens aperture, shutter speed, etc) of a camera for correct light exposure of the photographic material.

7.32 Goniophotometer — Photometer for measuring the directional light distribution characteristics of sources, lighting fittings, media and surfaces.

Note — A goniophotometer for measuring the spatial distribution of luminous intensity is also called a distribution photometer.

7.33 Gloss of a Surface — Directionally selective reflecting properties responsible for the degree to which reflected highlights or the image of objects may be seen as superimposed on the surface.

7.34 Instrument tor Glossmeter — Apparatus for measuring gloss expressed as a function of the regular and diffuse reflectances of the surface of an object.

7.35 Colour Correction Factor for a Physical Photometer — The factor by which the readings of a physical photometer shall be multiplied in order to obtain values in conformity with the V (λ) function, for radiation of a relative spectral energy distribution different from that by which the photometer was calibrated.

7.36 Dispersion and Mask (Template) Method — Method of physical photometry and colorimetry in which the conditions needed to give results in conformity with the V (λ) function or the colour-matching functions are obtained by dispersing the light into a spectrum and masking this with a diaphragm of such a shape that it transmits the desired fraction of the flux at every wavelength.

7.37 Cascade (Step-by-Step) Method of Comparison — Method of heterochromatic photometry in which the colour difference between two lights is bridged by making a series of intermediate comparisons, each with a small colour difference.

7.38 Life of a Lamp — Time during which a lamp has been operated before becoming useless or considered as such according to certain specifications.

NOTE — The life is generally expressed in hours.

7.39 Rated Life of Type of Lamp — Declared life determined by means of life tests on lamps of the same type.

7.40 Life Test — Test in which lamps are operated under specified conditions for a specified time and during which photometric measurements may be made at specified intervals.

7.41 Physical Receptor Radiation — Instrument in which a measurable physical effect is produced by the action of the radiation it receives.

7.42 Photoelectric Effect — Interaction between radiation and matter resulting in the absorption of photons and the consequent liberation of electrons.

7.42.1 *External Photoelectric Effect* — Photoelectric effect in which electrons are ejected from the material.

7.42.2 *Internal Photoelectric Effect* — Photoelectric effect produced in a semiconductor by the movement of electrons to a higher energy band followed by the appearance of free electric charges in the interior of the material.

7.42.3 *Photovoltaic Effect* — Internal photoelectric effect characterized by the production of an electromotive force in the neighbourhood of a *p-n* junction.

7.43 Secondary (Electron) Emission — Electron emission due to the bombardment of a surface by electrons or ions.

7.44 Photoelectric Receptor; Photocell — Physical receptor that depends for its action on an external or internal photoelectric effect.

7.45 Phototube; Photoemissive Cell — Photoelectric receptor comprising a vacuum or gas-filled electronic tube containing a cathode capable of emitting electrons by the external photoelectric effect.

7.46 Photomultiplier — Phototube in which the electron current emitted by the cathode is amplified by secondary electron emission from one or generally several intermediate electrodes in succession known as *dynodes*.

7.47 Photoconductive Cell — Photoelectric receptor utilizing a semiconductor in which absorption of radiation gives rise to an increase in conductivity by the internal photoelectric effect.

7.48 Photovoltaic Cell — Photoelectric receptor in which absorption of radiation in the neighbourhood of a *p-n* junction between two semiconductors, or of a contact between a semiconductor and a metal, produces a change of resistance, depending on the current direction.

7.49 Photodiode — Photoelectric receptor in which absorption of radiation in the neighbourhood of a *p-n* junction between two semiconductors, or of a contact between a semiconductor and a metal, produces an electromotive force.

7.50 Phototransistor — Photoelectric receptor utilizing semi-conductors in which the photoelectric effect is produced in the neighbourhood of a double *p-n* junction (*p-n-p*, or *n-p-n*) possessing amplification properties.

7.51 Photoelectric Current — That part of the electric current in a photoelectric receptor which is produced by the photoelectric effect.

7.52 Dark Current — That part of the electric current in the photoelectric receptor which still flows when the receptor receives no radiation capable of producing a photoelectric effect.

7.53 Thermal Receptor of Radiation — Physical receptor in which a measurable effect occurs due to the heating of the part that absorbs the radiation.

7.54 (Radiation) Thermocouple — Thermal receptor in which the absorbed radiation produces, by the heating of a contact between two conductors of different kinds, an electromotive force by the thermoelectric, or seeback, effect.

7.55 Radiation (Thermopile) — Thermal receptor comprising a number of thermocouples.

7.56 Bolometer — Thermal receptor in which the heating of the part that absorbs the radiation gives rise to a change in its electrical resistance.

7.57 Pneumatic Receptor of Radiation — Thermal receptor in which the heating of the part that absorbs the radiation gives rise to a change in the pressure of a gas.

8. THE PRODUCTION OF LIGHT

8.1 Primary Light Source — Surface or object emitting light which is produced by a transformation of energy.

8.2 Secondary Light Source — Surface or object which is not self-emitting but receives light and returns it, at least in part, by reflection or transmission

8.3 Lamp — Source made in order to produce light.

8.4 Excitation of a Gas — Elevation of the atoms or molecules of a gas to higher energy levels.

8.5 Energy Level — Discrete state of excitation of an atom or molecule, characteristic of the excitation energy which it holds.

8.6 Life-Time of Excited State — The most probable length of time for which an atom or a molecule remains in the excited state.

8.7 Resonance Line — Spectral line which appears both as an emission line and as an absorption line and which is the result of direct passage from an excited state to the ground state, or *vice versa,* without going through intermediate levels (for example, Hg 253·7 mm).

8.8 Luminescence — Phenomenon of the emission by matter of electromagnetic radiation which for certain wavelengths or restricted regions of the spectrum is in excess of that due to the thermal radiation from the material at the same temperature. The radiation is characteristic of the particular material.

Note — In lighting, this term is generally restricted to the emission of radiation in the visible or near visible spectrum.

8.9 Incandescence — Emission of visible radiation by thermal excitation.

8.10 Electroluminescence — Luminescence of certain substances, generally solid, under the action of an electric field.

Note — Formerly this term has been used chiefly for the luminescence of a gas under the action of an electric discharge.

8.11 Photoluminescence — Luminescence caused by ultraviolet, visible or infrared radiation.

8.12 Chemi-Luminescence — Luminescence due to the energy liberated in a chemical reaction.

8.13 Tribo-Luminescence — Luminescence due to the fracture of crystal lattices.

8.14 Fluorescence — Photoluminescence which persists for an extremely short time after excitation.

Note — This time is generally less than about 10^{-8} s. An exact definition of this phenomenon is beyond the scope of this vocabulary.

8.15 Phosphorescence — Photoluminescence which persists for an appreciable time after excitation.

Note — This time is generally more than about 10^{-8} s. An exact definition of this phenomenon is beyond the scope of this vocabulary.

8.16 Cathode Fall — The difference of potential due to the space charge near the cathode.

NOTE — In the case of a glow discharge a distinction is made between the normal cathode fall, which occurs when the glow does not cover the cathode completely (the current density remaining constant) and which is independent of the current in the discharge, and the *abnormal cathode fall*, which occurs when the glow covers the cathode completely (which increased current density) and which depends on the current in the discharge.

8.17 Electric Discharge in a Gas — The passage of an electric current through gases and vapours, by the production and movement of charge carrier under the influence of an electric potential. This results in the emission of electromagnetic radiation, the effect of which is basic in all applications of this phenomenon in lighting.

8.18 Glow Discharge — Discharge in which the secondary emission from the cathode is much greater than the thermionic emission.

NOTE — This discharge is characterized by a considerable cathode fall (70 V or more) and by low current density at the cathode (some 10 A-m^{-2}).

8.19 Arc Discharge; Electric Arc in a Gas — Discharge characterized by a cathode fall which is small compared with that in a glow discharge.

NOTE — The electron emission of the cathode is due to various causes (thermionic emission, high field emission, etc) acting simultaneously or separately, but secondary emission plays only a small part.

8.20 Arc — The luminous column of gas in an arc discharge.

8.21 Crater — The cavity which in a direct current arc lamp is produced at the end of the positive carbon.

8.22 Starting Voltage — The lowest voltage between the electrodes which is needed to start the discharge in a lamp

8.23 Lamp (Tube) Voltage — The voltage between electrodes of a discharge lamp during stable operating conditions (the effective voltage in the case of alternating current).

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